Interannual Variability in Tropical Radiation and Water Vapor

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More than any other factor, the presence of water defines the unique characteristics of climate on planet Earth. Evaporation from the ocean/land surface and trapping of upwelling longwave radiation by atmospheric water vapor are processes that moderate climate at the surface. At present it is uncertain how variability in the global hydrologic cycle, whether natural or anthropogenic, will modify climate in the future. As part of NASA's Mission To Planet Earth (MTPE) research program, we are using a combination of infrared satellite measurements and numerical models to study short-term climate variations and the role that water plays in these. In particular the phenomena known as El Niño is a frequent but aperiodic readjustment of tropical climate that provides us a natural "laboratory" in which to study the dynamics of water in climate. An El Niño event together with a subsequent readjustment phase known as La Nina, may take two to three years to complete. This time span is short enough to be monitored by individual satellite sensors measuring temperature, moisture, and upwelling radiation from the planet.

The key issue that we have focused on in the past year is the impact of El Niño-related water vapor changes on outgoing longwave clear-sky radiation (LWCS) during the period 1987 through 1989. The fundamental statistic of interest is the change in LWCS with change in sea-surface temperature (SST) averaged over the tropical oceans (30 degrees north to south). Fortunately, three independent data bases of LWCS were available during this period. Because maximum excursions in area-mean LWCS are of the order 3.0 Wm^{-2}, or about 1 percent of the climatological LWCS value, it is important to understand the effects of biases and random errors. Intercomparing these three data bases has enabled us to greatly enhance our confidence in our result.

Figure 149 shows a time series for each of three LWCS data sets: the Earth Radiation Budget Satellite (ERBS); University of Maryland's high-resolution infrared sounder (UMD HIRS); and TIROS operational vertical sounder (TOVS Path A). Also shown is the tropical average SST from National Oceanic and Atmospheric Association's (NOAA) Climate Analysis Center. These time series are composed of monthly mean departures, or anomalies, from their respective 3-year monthly climatology. Also shown is a calculation of LWCS anomalies we would expect if there were no variability in atmospheric water vapor. Each data set shows a general tendency for the Earth/atmosphere system to emit more LWCS as tropical ocean SST's increase during the onset of El Niño in 1987. A decrease in LWCS is seen in 1988/1989 as SST's decrease during La Nina. However, the amplitudes of this response are seen to differ. Through our analysis of the measurement strategies we have found that the ERBS sensor has too little dynamic range, due mostly to difficulties in properly distinguishing partly cloudy scenes from those that are clear but have abundant water vapor present. We also suspect that each of the three methods is subject to some error arising from the inability to screen very thin high ice clouds when looking almost vertically. Sensitivity studies indicate that biases arising from this effect are only several tenths Wm^{-2}.

If we calculate the slope of the quantity (LWCS anomaly/SST anomaly), or ΔLWCS/ΔSST from the data in figure 149, we obtain: ERBS (1.67 $Wm^{-2}K^{-1}$), UMD (2.93 $Wm^{-2}K^{-1}$), and TOVS Path A (2.77 $Wm^{-2}K^{-1}$). These slopes are

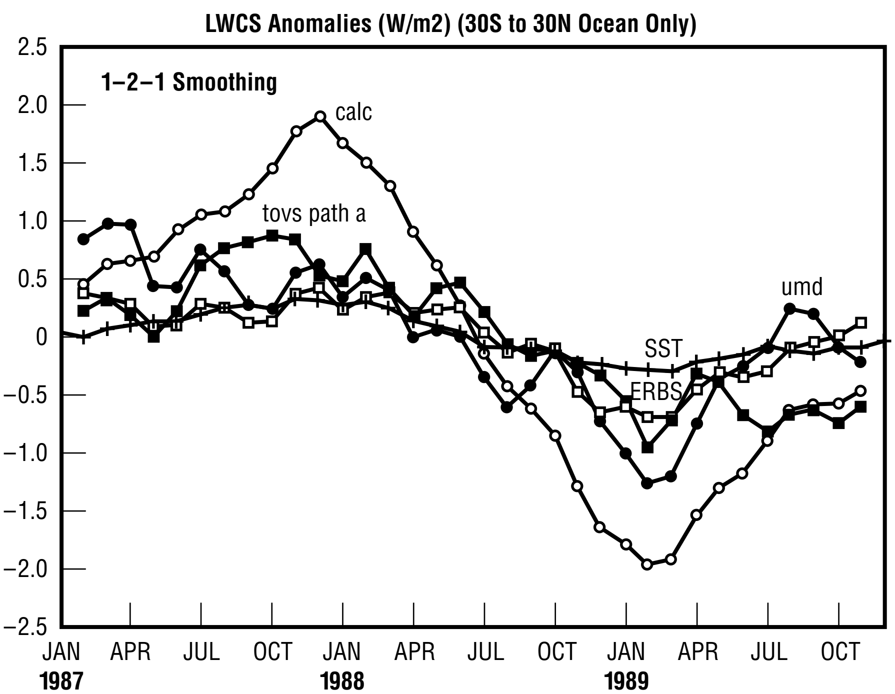

FIGURE 149.—L2WCS estimates from three satellite-based algorithms (ERBS, TOVS, Path A, UMD HIRS) and a radiative model calculation (calc).

important because of what they tell us about changes in greenhouse trapping of LWCS by changes in atmospheric water vapor and temperature induced by El Niño/La Nina. If the greenhouse trapping, or ratio of LWCS measured by satellite at the top-of-atmosphere to the LWCS emitted by the ocean surface were constant during this period, we would expect the slope ΔLWCS/ΔSST to be about 3.9 $Wm^{-2}K^{-1}$. Each of our estimates of the actual ΔLWCS/ΔSST is substantially smaller. This suggests that during warm SST periods, more LWCS radiation is being trapped by increased water vapor. Sensitivity analyses indicate that ERBS is about 1.5 $Wm^{-2}K^{-1}$ too small, while UMD and TOVS Path A are of the order 10 percent too small. Even with these adjustments our conclusion still holds: During El Nino, changes in atmospheric water vapor and thermal structure act to retard LWCS cooling of the tropical oceanic regions.

Our current efforts are directed to two areas. First, we are conducting radiative modeling studies to separate atmospheric temperature effects from water vapor effects. Our initial results suggest that temperature changes enhance radiative losses to space during El Niño, while water vapor is the agent that retards radiative loss. Our other area of focus is to determine the extent to which water vapor changes during El Niño and La Nina, when averaged over the tropical oceans, are the result of moisture transport by winds from the tropical land areas. This other mechanism for moisture supply would be in-situ ocean surface evaporation.

This ongoing research is supported under the office of MTPE and constitutes an important inquiry into how the hydrologic cycle is involved in climate variability. The three data sets used are forerunners of more precise measurements to be undertaken by the Earth-observing component of MTPE. We anticipate that in the near term these results will be of use in validating climate models which use the 1987/1989 period as a test case. We have performed some of these type studies in house with the GENESIS climate model. We also expect the results of this study to phase well with the Tropical Rainfall Measuring Mission (TRMM). Since tropical precipitation releases energy to heat the tropics and drive planetary wind fields, our studies will provide some insight as to how this heat is rejected back to space and exported to higher latitudes to maintain the global heat balance.

Robertson, F.R.; Fitzjarrald, D.; Braswell, W.D.: “Anomalies in Radiation, Heat and Water Budgets as Diagnosed from Pre-EOS Data Sets: Insights on Tropical Climate Sensitivity.” 1996 NOAA Climate Diagnostics Workshop, Huntsville, AL, October 27–November 1, 1996.

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Biographical Sketch: Dr. Franklin Robertson (Ph.D. Purdue University, 1981) leads the Climate Diagnostics and Modeling Group in studying water and its influence on the atmosphere and climate dynamics. He serves as the lead MSFC investigator on a joint EOS interdisciplinary investigation “The Global Water Cycle: Extension Across the Earth Sciences,” conducted jointly with Pennsylvania State University. Robertson has also contributed to the formulation of science strategies for a NASA space-borne lidar to measure atmospheric wind measurements critical to studies of the global energy and water cycle.